

APPENDIX D

SELECTION OF RADIONUCLIDES FOR RADIOLOGICAL ASSESSMENT

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SELECTION OF RADIONUCLIDES FOR RADIOLOGICAL ASSESSMENT

D.1 SOURCES USED TO MAKE RECOMMENDATIONS

The following sources were reviewed and used to arrive at the recommendations as to which long-lived (i.e., half-lives greater than six months) radionuclides should be included in the present analysis. The nuclides selected from each source and considered as candidates for the analysis are listed in Table D-6. Each source is referred to by a mnemonic or a short title, which in most cases is the document number.

D.1.1 IAEA-TECDOC-855

Table I of “Clearance Levels for Radionuclides in Solid Materials: Application of Exemption Principles” (IAEA 1996) presents clearance levels—expressed in units of Bq/g—for the unconditional release of material with radioactive contamination. To determine these levels, the IAEA reviewed a large number of documents. The following four documents are relevant to the release of metals (including steel, aluminum, and copper): “Principles for the Exemption of Radiation Sources and Practices from Regulatory Control,” Safety Series No. 89 (IAEA 1988); “Radiological Protection Criteria for the Recycling of Materials from Dismantling of Nuclear Installations,” Radiation Protection No. 43 (CEC 1988); “Basis for Criteria for Exemption of Decommissioning Waste” (Elert et al. 1992); and “Radiological Impacts of Very Slightly Radioactive Copper and Aluminium Recovered from Dismantled Nuclear Facilities” (Garbay and Chapuis 1991). The radionuclides that were included in the radiological assessments of clearance (along with their respective release limits) in each of these four documents are listed in Table I.3 of IAEA 1996. Only those nuclides that are associated with clearance of metals are considered as candidates for the present analysis.

D.1.2 NUREG/CR-0134

In “Potential Radiation Dose to Man from Recycle of Metals Reclaimed from a Decommissioned Nuclear Power Plant,” NUREG/CR-0134 (O’Donnell et al. 1978), the authors present individual and population dose factors resulting from scrap metal recycle for 27 radionuclides. These nuclides “... include fission and activation products (except gaseous species) that may be encountered during decommissioning, and that have radioactive half-lives longer than about 40 days, ^{239}Pu and ^{241}Am (to characterize transuranic contaminants), and ^{234}U , ^{235}U , and ^{238}U .”

D.1.3 WINCO-1191

The radionuclides reported in “Radionuclides in the United States Commercial Nuclear Power Reactors,” WINCO-1191 (Dyer 1994) were taken from a study of pipe samples and pipe surface contamination from pressurized and boiling water reactors; they are listed in Table D-1. The samples were from 11 pressurized water reactors (PWRs) and "over" eight boiling water reactors (BWRs). The data were based on surface samples taken from the inside of stainless steel piping, a main coolant system check valve, and from fuel element hardware. The study also includes an analysis of the Shippingport reactor material samples. Radionuclides that are found exclusively in the coolant or within the fuel cladding are not considered to be candidates for inclusion in the present analysis.

The study notes that between 86% and 99% of the activities from the pipe walls and pipe surfaces are the activation products Fe-55, Co-60, and Ni-63. The author goes on to note that the distribution of radionuclides in reactor component appears to be the same whether the activities are on surfaces or are within the metal.

D.1.4 NUREG/CR-0130

Appendix J of “Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station,” NUREG/CR-0130 (Smith et al. 1978) presents five sets of “reference radionuclide inventories” that were used to characterize a PWR at the time of its decommissioning. Four of the reference inventories are associated with contaminated metal components, and are listed in Table D-2, while the fifth set is for contaminated concrete, and is not relevant to the present study.

The metals removed during PWR decommissioning which are contaminated with either activated corrosion products or surface contamination would be candidates for recycling. The authors include the “stainless and carbon steel activation products” classes of radionuclides, which are the contaminants on the reactor vessel and its internals. In a PWR at the time of decommissioning, this metal would be too highly activated to be a candidate for recycling. However, stainless and carbon steel can become activated by other means, or a reactor may have operated for only a short time (e.g., Shoreham), therefore, the radionuclides in these two sets are candidates for inclusion in the present analysis.

Table D-1. Nuclides from WINCO-1191

Nuclide	Half-Life (y)	Surface Activity at Shutdown ($\mu\text{Ci}/\text{cm}^2$)
C-14 ^a	5.73e+03	< 5.9e-08
Mn-54 ^a	8.55e-01	6.9e-03
Fe-55 ^a	2.73e+00	2.7
Co-57 ^b	7.44e-01	1.78e-05
Ni-59 ^a	7.60e+04	6.80e-03
Co-60 ^a	5.27e+00	2.0
Ni-63 ^a	1.00e+02	1.55
Zn-65 ^b	6.69e-01	1.68e-06
Nb-93m ^a	1.46e+01	1.2e-02
Nb-94 ^a	2.03e+04	8.4e-05
Ag-110m ^b	6.84e-01	1.3e-04
Mo-93 ^c	3.50e+03	1.8e-08 ^d
Sb-125 ^c	2.76e+00	1.0e-05 ^d
I-129 ^a	1.57e+07	<1.6e-08
Ce-144+D ^b	7.81e-01	2.49E-6
Pu-238 ^a	8.77e+01	1.2e-07
Pu-239/240 ^a	2.41e4/6.56e3	4.7e-08
Cm-244 ^a	1.81e+01	2.6e-08

^a Sample taken from Shippingport B-loop Primary Coolant Check Valve. Total activity in sample: 6.27 $\mu\text{Ci}/\text{cm}^2$.

^b Sample taken from Ranch Seco Nuclear Power Plant. Total activity in sample: 0.252 $\mu\text{Ci}/\text{cm}^2$.

^c Sample taken from Shippingport reactor internals. Total activity in sample: 3.85E-3 $\mu\text{Ci}/\text{g}$.

^d Specific activity ($\mu\text{Ci}/\text{g}$)

Konzek et al. (1995) revised the PWR decommissioning analysis originally presented by Smith et al. (1978) to reflect current regulations, practices and costs. The authors did not re-analyze the radiological source terms presented in Appendix C by Smith et al. (1978), although they did use “as built” drawings, rather than design drawings, for estimating the volume of waste material and equipment (Bierschbach 1996). This could change the radionuclide inventories but would not result in any major changes to the expected radionuclide distributions in PWR components at the time of decommissioning.

Table D-2. Nuclides Included in NUREG/CR-0130

Nuclide	Stainless Steel AP ^a	Carbon Steel AP	Activated Corrosion Products	Surface Contamination
Mn-54	✓ ^b	✓	✓	✓
Fe-55	✓	✓	--	✓
Co-60	✓	✓	✓	✓
Ni-59	✓	✓	--	--
Ni-63	✓	✓	--	--
Zn-65	✓	--	--	--
Sr-90	--	--	--	✓
Mo-93	✓	✓	--	--
Nb-94	✓	--	--	--
Ru-106	--	--	✓	--
Cs-134	--	--	--	✓
Cs-137	--	--	✓	✓

^a AP = activation product

^b A check mark (✓) indicates that the radionuclide is included in the NUREG/CR-0130 reference inventory.

D.1.5 NUREG/CR-3585

In “De Minimis Impacts Analysis Methodology,” NUREG/CR-3585, (Oztunali and Roles 1984), the authors present an analysis of the impacts of clearance of metals. Any metal which met the *de minimis* activity level would have been considered to be a candidate for clearance, since it would no longer have been under regulatory control.

D.1.6 NUREG/CR-4370

“Update of Part 61 Impacts Analysis Methodology,” NUREG/CR-4370 (Oztunali and Roles 1986) was reviewed as a source of information concerning the radiological profile of scrap which would be disposed of as low-level waste—cleared scrap would have a similar profile. The report analyzed 53 radionuclides, increased from the 23 analyzed in the original Part 61 analysis methodology. Table D-3 list these 53 nuclides.

Oztunali and Roles (1986) identified 148 waste streams, for which they developed radionuclide characterizations. Only three of the 148 streams are directly applicable to the recycling of scrap:

1. The nuclear power plant decommissioning contaminated metals
2. The West Valley Demonstration Project equipment and hardware
3. Non-compressible trash

Table D-3. Nuclides Analyzed in NUREG/CR-4370

Nuclide	Notes	Nuclide	Notes	Nuclide	Notes
H-3	a, b, c	Cs-135	a, b, c	U-236	c
C-14	a, b, c	Cs-137	a, b, c	U-238	a, c
Na-22	NI	Eu-152	b	Np-237	a, b, c
Cl-36	--	Eu-154	b	Pu-236	c
Fe-55	a, c	Pb-210	NI	Pu-238	a, b, c
Co-60	a, c	Ac-227	HLW	Pu-239	a, b, c
Ni-59	a, c	Th-228	--	Pu-240	a, c
Ni-63	a, b, c	Th-229	NI	Pu-241	a, b, c
Sr-90	a, b, c	Rn-222	NI	Pu-242	a, b, c
Nb-94	a, c	Ra-226	--	Pu-244	NI
Tc-99	a, b, c	Ra-228	NI	Am-241	a, b, c
Ru-106	b	Th-230	HLW	Am-243	a, b, c
Ag-108m	NI	Th-232	NI	Cm-242	b, c
Cd-109	NI	Pa-231	HLW	Cm-243	a, b, c
Sn-126	b	U-232	HLW	Cm-244	a, b, c
Sb-125	b	U-233	--	Cm-248	HLW
I-129	a, b, c	U-234	c	Cf-252	HLW
Cs-134	b	U-235	a, c		

a Associated with the nuclear-power-plant-decommissioning contaminated metals waste streams

b Associated with the West Valley Demonstration Project equipment and hardware waste streams

c Associated with non-compressible trash waste streams

NI Nuclide was not included in the characterization of any of the waste streams in NUREG/CR-4370, may be included as a decay product of another nuclide which is included in the waste stream characterization.

HLW Nuclide was only included in the spent fuel reprocessing high-level liquid waste stream.

D.1.7 SAND92-0700

In volume 3 of the “Preliminary Performance Assessment for the Waste Isolation Pilot Plant,” SAND92-0700/3, Peterson (1992) estimates the radionuclide inventories in DOE-generated

transuranic (TRU) waste that would be disposed of at the Waste Isolation Pilot Project (WIPP). Because the radionuclides present in TRU waste are a likely source of the contamination of metals present at DOE facilities, Peterson's memo is included in the present review. The memo classified TRU waste as to whether it can be contact handled (CH) or whether remote handling (RH) is required. Both types of TRU waste are considered for the scrap recycle analysis—Table D-4 indicates the type of TRU waste in which the radionuclide may be found.

Table D-4. Nuclides Analyzed by SAND92-0700 for WIPP

Nuclide	Half-Life (y)	RH ^a	CH ^b	Nuclide	Half-Life (y)	RH ^a	CH ^b
Mn-54	8.56e-01	✓	—	Th-232	1.41e+10	✓	✓
Co-60	5.27e+00	✓	—	U-233	1.59e+05	✓	✓
Ni-63	1.00e+02	✓	—	U-235	7.05e+08	✓	✓
Sr-90	2.91e+01	✓	✓	U-236	2.34e+07	✓	—
Tc-99	2.13e+05	✓	—	U-238	4.47e+09	✓	✓
Ru-106	1.01e+00	✓	✓	Np-237	2.14e+07	✓	✓
Sb-125	2.77e+00	✓	—	Pu-238	8.77e+01	✓	✓
Cs-134	2.06e+00	✓	—	Pu-239	2.41e+04	✓	✓
Cs-137	3.00e+01	✓	✓	Pu-240	6.56e+03	✓	✓
Ce-144	7.78e-01	✓	✓	Pu-241	1.44e+01	✓	✓
Pm-147	2.62e+00	✓	✓	Pu-242	3.75e+05	✓	✓
Eu-152	1.33e+01	✓	—	Am-241	4.33e+02	✓	✓
Eu-154	8.80e+00	✓	—	Cm-244	1.81e+01	✓	✓
Eu-155	4.96e+00	✓	—	Cf-252	2.64e+00	✓	✓

^a Waste requires remote handling due to high external exposure rate

^b Waste can be handled by direct contact

D.1.8 ORIGEN

The Oak Ridge Isotope Generation and depletion code (ORIGEN) (Croff 1980) includes a radionuclide library with approximately 1,700 entries collected into three groups: activation products, transuranics, and fission products. Included are 1,040 individual nuclides (a given nuclide can appear in more than one group), 127 of which have half-lives greater than six months.

To determine which of these 127 radionuclides should be included in the present analysis, an ORIGEN analysis was performed to calculate the activity in spent fuel at the time of discharge from the reactor. An initial enrichment of 3.04% U-235 was assumed, with a burnup of 44,340 MW-days per metric ton of initial heavy metal (MWD/MTIHM), and the characteristics of PWR fuel with impurities. For the purpose of this selection process, it was assumed that the specific activity of a given nuclide in scrap metal from a nuclear facility would be proportional to its activity in the spent fuel inventory. Furthermore, it was assumed that the dose to an exposed individual from a given nuclide, via one of the three pathways (inhalation, ingestion and external exposure) considered in the radiological assessments presented in the main body of this report, would be proportional to the dose conversion factor (DCF) for that pathway. (The DCFs are listed in Federal Guidance Reports (FGR) No. 11 [Eckerman et al. 1988] for internal exposure and No. 12 [Eckerman and Ryman 1993] for external exposure.)¹ We therefore assigned a “significance,” which we define as the product of the activity in spent fuel and the DCF, to each of the 127 nuclides. For each pathway, we found the nuclide with the highest significance. We then calculated the ratio of the significance of each nuclide for each pathway to the significance of the maximum nuclide—the one with the highest significance

$$R_{ij} = \frac{A_i F_{ij}}{A_{m_j} F_{m_j,j}}$$

where:

R_{ij} = significance ratio for radionuclide i and pathway j

¹ The scoping analysis described in this section was performed in support of the 1997 Draft “Technical Support Document: Evaluation of the Potential for Recycling of Scrap Metals from Nuclear Facilities.” This scoping analysis was but one of nine criteria used in the radionuclide selection process, and contributed at most 2 points out of a possible score of 30. Although the radiological assessments presented in the main body of the present report utilized the revised internal exposure DCFs from ICRP Publication 68 (ICRP 1994), it is unlikely that the selected radionuclides would change if the more current DCFs were used in the selection process.

- A_i = spent fuel activity for radionuclide i
 F_{ij} = dose conversion factor for radionuclide i in pathway j (FGR 11 for internal, FGR 12 infinite soil coefficients for external)
 $A_{m,j}$ = spent fuel activity for radionuclide with the maximum significance for pathway j
 $F_{m,j}$ = DCF for the radionuclide with the maximum significance for pathway j

The results of this scoping analysis are listed in Table D-5.

D 1.9 SAND91-2795

The “Yucca Mountain Site Characterization Project, TSPA 1991: An Initial Total-System Performance Assessment for Yucca Mountain, SAND91-2795 (Barnard et al. 1992) presents an analysis of the impacts from the disposal of spent fuel. Because the radionuclides present in spent fuel are a likely source for the contamination of metals present in nuclear power plants and other tail-end fuel cycle facilities, this report was included in the present review.

D.2 RADIONUCLIDES RECOMMENDED FOR INCLUSION

Table D-6 lists all radionuclides with half-lives greater than six months which were included in the present review. A check mark (✓) in the last column of Table D-6 indicates that that radionuclide is recommended for inclusion in the scrap recycle analysis. The basis for these recommendations is discussed below.

D.2.1 Basis for Recommendations

A recommendation to include a radionuclide in the scrap recycle analysis is based on the following:

- Each of the sources reviewed was assigned a weighting factor, depending on its applicability to scrap recycle. The weighting factors range from 6 for those sources which are most applicable to scrap recycle to 2 for those documents which are least applicable. These weighting factors are shown in parentheses below the designation of each source document in the heading of Table D-6.

Table D-5. Nuclides from ORIGEN with Normalized Activity-Weighted Dose Factors

Nuclide	∞ Soil	Inhalation	Ingestion	Nuclide	∞ Soil	Inhalation	Ingestion
H-3	0.00e+00	3.04e-08	2.31e-06	Rh-102	1.16e-05	1.27e-07	8.42e-07
Be-10	2.96e-15	1.16e-12	1.15e-12	Pd-107	0.00e+00	1.09e-09	9.72e-10
C-14	3.95e-12	7.27e-10	5.51e-08	Ag-108m	6.40e-08	2.23e-09	4.54e-09
Na-22	0.00e+00	0.00e+00	0.00e+00	Ag-110m	6.04e-02	3.35e-04	3.42e-03
Si-32	2.09e-16	2.16e-14	1.74e-14	Cd-109	9.07e-09	8.36e-08	7.29e-07
Cl-36	1.38e-11	1.50e-10	1.57e-09	Cd-113m	2.45e-08	6.86e-05	5.48e-04
Ar-39	3.33e-14	0.00e+00	0.00e+00	In-115	2.30e-21	2.53e-17	8.10e-17
Ar-42	Not in FGR 11 or 12			Sn-119m	4.15e-07	1.02e-06	1.73e-05
K-40	2.73e-15	3.85e-17	4.39e-15	Sn-121m	2.57e-10	1.72e-09	2.47e-08
Ca-41	0.00e+00	1.49e-13	1.07e-11	Sn-126	5.11e-06	5.19e-08	8.19e-07
V-49	0.00e+00	0.00e+00	0.00e+00	Sb-125	1.94e-02	1.31e-04	2.61e-03
V-50	Not in FGR 11 or 12			Te-123	1.20e-20	2.28e-20	6.86e-19
Mn-54	4.64e-06	7.15e-09	2.24e-07	I-129	2.15e-10	3.42e-09	4.13e-07
Fe-55	0.00e+00	1.63e-08	2.79e-07	Cs-134	1.00e+00	5.79e-03	6.96e-01
Co-60	8.77e-04	1.40e-05	1.31e-04	Cs-135	6.88e-12	9.70e-10	1.14e-07
Ni-59	0.00e+00	1.66e-11	9.79e-11	Cs-137	1.81e-01	2.01e-03	2.38e-01
Ni-63	0.00e+00	6.27e-09	4.36e-08	Ba-133	1.75e-36	8.16e-39	2.70e-37
Zn-65	2.44e-04	1.59e-06	8.55e-05	La-137	0.00e+00	0.00e+00	0.00e+00
Se-79	3.75e-12	2.35e-09	1.58e-07	La-138	7.05e-15	1.44e-15	4.69e-16
Kr-81	1.05e-14	0.00e+00	0.00e+00	Ce-142	Not in FGR 11 or 12		
Kr-85	6.17e-05	0.00e+00	0.00e+00	Ce-144	1.71e-01	2.33e-01	1.00e+00
Rb-87	1.37e-15	3.73e-14	4.31e-12	Nd-144	Not in FGR 11 or 12		
Sr-90	8.11e-04	5.09e-02	4.53e-01	Pm-145	0.00e+00	0.00e+00	0.00e+00
Zr-93	0.00e+00	3.24e-07	1.27e-07	Pm-147	2.27e-06	2.11e-03	4.28e-03
Nb-91	Not in FGR 11 or 12			Pm-146	8.39e-06	3.31e-07	6.28e-07
Nb-93m	6.54e-12	2.18e-09	2.95e-09	Sm-145	0.00e+00	0.00e+00	0.00e+00
Nb-94	8.24e-10	4.18e-11	5.47e-11	Sm-146	0.00e+00	1.10e-11	2.05e-12
Mo-93	2.15e-13	1.23e-11	4.42e-11	Sm-147	0.00e+00	4.46e-11	8.40e-12
Tc-97	0.00e+00	0.00e+00	0.00e+00	Sm-148	Not in FGR 11 or 12		
Tc-98	3.48e-11	1.10e-13	1.78e-12	Sm-149	Not in FGR 11 or 12		
Tc-99	7.79e-10	6.13e-08	8.16e-07	Sm-151	1.72e-10	6.23e-06	6.13e-06
Ru-106	4.30e-01	1.88e-01	8.20e-01	Eu-152	1.68e-05	6.26e-07	1.39e-06
Eu-154	5.38e-02	2.37e-03	6.01e-03	U-233	7.03e-15	8.08e-10	1.31e-10

Table D-5 (continued)

Nuclide	∞ Soil	Inhalation	Ingestion	Nuclide	∞ Soil	Inhalation	Ingestion
Eu-155	8.27e-04	2.23e-04	6.24e-04	U-234	1.32e-10	5.17e-05	8.40e-06
Eu-150	7.03e-11	2.56e-12	4.62e-12	U-235	2.89e-09	5.57e-07	9.20e-08
Gd-152	0.00e+00	2.76e-17	1.38e-18	U-236	2.16e-11	1.50e-05	2.43e-06
Gd-153	6.08e-06	7.01e-07	2.62e-06	U-238	1.80e-08	1.67e-05	2.87e-06
Tb-157	0.00e+00	0.00e+00	0.00e+00	Np-235	1.42e-11	2.16e-11	9.59e-11
Ho-163	Not in FGR 11 or 12			Np-236	1.71e-12	4.58e-10	2.89e-10
Ho-166m	3.24e-08	2.88e-09	2.28e-09	Np-237	1.76e-07	1.03e-04	6.40e-05
Tm-171	2.01e-12	1.95e-11	6.96e-11	Pu-236	1.10e-10	8.24e-05	5.04e-05
Lu-176	4.83e-33	1.50e-33	1.26e-33	Pu-238	2.51e-07	7.71e-01	4.77e-01
Hf-182	0.00e+00	0.00e+00	0.00e+00	Pu-239	3.99e-08	6.88e-02	4.30e-02
Ta-180	0.00e+00	0.00e+00	0.00e+00	Pu-240	3.36e-08	1.17e-01	7.30e-02
Re-187	0.00e+00	1.81e-19	2.41e-18	Pu-241	1.35e-06	7.00e-01	4.41e-01
Os-194	5.32e-17	7.74e-17	1.41e-16	Pu-242	1.74e-10	6.63e-04	4.12e-04
Ir-192m	1.84e-14	1.68e-15	2.25e-15	Pu-244	1.38e-12	3.28e-10	2.05e-10
Pt-190	Not in FGR 11 or 12			Am-241	2.83e-06	3.41e-02	2.12e-02
Pt-193	1.73e-19	8.25e-18	3.27e-16	Am-242m	2.73e-07	2.09e-03	1.30e-03
Tl-204	0.00e+00	0.00e+00	0.00e+00	Am-243	1.68e-05	9.82e-03	6.14e-03
Pb-204	Not in FGR 11 or 12			Cm-243	1.14e-05	7.12e-03	4.42e-03
Pb-205	6.92e-21	4.56e-18	1.44e-16	Cm-244	4.28e-07	1.00e+00	6.17e-01
Pb-210	1.39e-17	6.26e-14	1.49e-12	Cm-245	1.22e-07	1.93e-04	1.20e-04
Bi-208	Not in FGR 11 or 12			Cm-246	1.24e-11	5.71e-05	3.55e-05
Bi-210m	1.31e-14	8.51e-14	8.16e-14	Cm-247	8.17e-13	2.16e-10	1.35e-10
Ra-226	7.07e-14	6.43e-14	7.53e-13	Cm-248	1.31e-16	2.92e-09	1.82e-09
Ra-228	5.70e-18	5.73e-18	1.24e-16	Cm-250	4.83e-19	2.83e-15	1.77e-15
Ac-227	3.12e-13	1.24e-09	2.06e-10	Bk-249	4.75e-14	1.16e-08	7.59e-09
Th-228	1.26e-08	5.06e-07	8.98e-08	Cf-249	4.21e-12	1.56e-09	9.69e-10
Th-229	1.46e-13	2.35e-10	3.32e-11	Cf-250	1.27e-14	3.34e-08	2.06e-08
Th-230	9.83e-15	3.14e-09	4.01e-10	Cf-251	3.71e-13	4.91e-10	3.07e-10
Th-232	4.79e-21	1.79e-14	2.26e-15	Cf-252	3.21e-14	3.39e-08	1.78e-08
Pa-231	1.06e-12	8.47e-09	5.30e-09	Es-254	1.11e-12	9.71e-12	5.64e-12
U-232	5.60e-12	4.85e-06	7.31e-07				

- For each radionuclide identified in one or more of the sources reviewed, a score was calculated by summing the weighting factors for each source in which the radionuclide appeared. These scores are shown in the second column from the right (headed “score”) in Table D-6.
- Those radionuclides with a score of 10 or greater are recommended for inclusion in the scrap recycle analysis, as indicated by a check mark in the last column of Table D-6.
- Members of the thorium and uranium radioactive decay series have been recommended for inclusion even if they have scores below 10, to enable the radiological assessment of the entire series in secular equilibrium.

Table D-6. Selection of Nuclides to Be Included in Scrap Recycle Analysis

Nuclide	Source (weighting factor)									Score	Include
	NUREG/ CR-0134	IAEA 1996	WINCO 1191	NUREG/ CR-0130	NUREG/ CR-3585	NUREG/ CR-4370	SAND 92 -0700	ORIGEN	SAND 91-2795		
	(5)	(6)	(4)	(4)	(3)	(2)	(2)	(2)	(2)		
H-3	—	—	—	—	✓	✓	—	—	—	5	—
C-14	✓	—	✓	—	✓	✓	—	—	✓	16	✓
Na-22	✓	—	—	—	✓	—	—	—	—	8	—
Cl-36	—	—	—	—	✓	—	—	—	✓	5	—
Mn-54	✓	✓	✓	✓	✓	—	✓	—	—	24	✓
Fe-55	✓	✓	✓	✓	✓	✓	—	—	—	24	✓
Co-57	—	—	✓	—	✓	—	—	—	—	7	—
Co-60	✓	✓	✓	✓	✓	✓	✓	✓	—	28	✓
Ni-59	✓	—	✓	✓	✓	✓	—	—	✓	20	✓
Ni-63	✓	✓	✓	✓	✓	✓	✓	—	✓	28	✓
Zn-65	✓	✓	✓	✓	✓	—	—	✓	—	24	✓
Se-79	—	—	—	—	—	—	—	—	✓	2	—
Rb-86	—	—	—	—	✓	—	—	—	—	3	—
Sr-90	✓	✓	—	✓	✓	✓	✓	✓	✓	26	✓
Zr-93	—	—	—	—	—	—	—	—	✓	2	—
Nb-93m	—	—	✓	—	—	—	—	—	—	4	—
Nb-94	—	✓	✓	✓	✓	✓	—	—	✓	21	✓
Mo-93	—	—	✓	✓	—	—	—	—	✓	10	✓
Tc-99	✓	✓	—	—	✓	✓	✓	—	✓	20	✓
Ru-106	✓	✓	—	✓	✓	✓	✓	✓	—	24	✓
Pd-107	—	—	—	—	—	—	—	—	✓	2	—

Table D-6 (continued)

Nuclide	Source (weighting factor)									Score	Include
	NUREG/ CR-0134	IAEA 1996	WINCO 1191	NUREG/ CR-0130	NUREG/ CR-3585	NUREG/ CR-4370	SAND 92 -0700	ORIGEN	SAND 91-2795		
	(5)	(6)	(4)	(4)	(3)	(2)	(2)	(2)	(2)		
Ag-108m	—	—	—	—	✓	—	—	—	✓	5	—
Ag-110m	—	✓	✓	—	✓	—	—	✓	—	15	✓
Cd-109	—	—	—	—	✓	—	—	—	—	3	—
Cd-113m	—	—	—	—	—	—	—	✓	—	2	—
Sn-121	—	—	—	—	—	—	—	—	✓	2	—
Sn-126	—	—	—	—	✓	✓	—	—	✓	7	—
Sb-125	—	—	✓	—	✓	✓	✓	✓	—	13	✓
I-129	—	—	✓	—	✓	✓	—	—	✓	11	✓
Cs-134	✓	✓	—	✓	✓	✓	✓	✓	—	24	✓
Cs-135	—	—	—	—	✓	✓	—	—	✓	7	—
Cs-137	✓	✓	—	✓	✓	✓	✓	✓	✓	26	✓
Ce-144	✓	✓	✓	—	✓	—	✓	✓	—	22	✓
Pm-147	—	✓	—	—	—	—	✓	✓	—	10	✓
Sm-151	—	—	—	—	—	—	—	—	✓	2	—
Eu-152	—	✓	—	—	✓	✓	✓	—	—	13	✓
Eu-154	—	—	—	—	✓	✓	✓	✓	—	9	—
Eu-155	—	—	—	—	—	—	✓	✓	—	4	—
Pb-210	—	—	—	—	✓	—	—	—	✓	5	✓
Ra-226	—	—	—	—	✓	—	—	—	✓	5	✓
Ra-228	—	—	—	—	✓	—	—	—	—	3	✓
Ac-227	—	—	—	—	✓	—	—	—	✓	5	✓

Table D-6 (continued)

Nuclide	Source (weighting factor)									Score	Include
	NUREG/ CR-0134	IAEA 1996	WINCO 1191	NUREG/ CR-0130	NUREG/ CR-3585	NUREG/ CR-4370	SAND 92 -0700	ORIGEN	SAND 91-2795		
	(5)	(6)	(4)	(4)	(3)	(2)	(2)	(2)	(2)		
Th-228	—	—	—	—	✓	—	—	—	—	3	✓
Th-229	—	—	—	—	✓	—	—	—	✓	5	✓
Th-230	—	—	—	—	✓	—	—	—	✓	5	✓
Th-232	—	—	—	—	✓	—	✓	—	—	5	✓
Pa-231	—	—	—	—	✓	—	—	—	✓	5	✓
U-232	—	—	—	—	✓	—	—	—	✓	5	—
U-233	—	—	—	—	✓	—	✓	—	✓	7	—
U-234	✓	✓	—	—	✓	✓	—	—	✓	18	✓
U-235	✓	✓	—	—	✓	✓	✓	—	✓	20	✓
U-236	—	—	—	—	✓	✓	✓	—	✓	9	—
U-238	✓	✓	—	—	✓	✓	✓	—	✓	20	✓
Np-237	—	✓	—	—	✓	✓	✓	✓	✓	17	✓
Pu-236	—	—	—	—	✓	✓	—	—	—	5	—
Pu-238	—	—	✓	—	✓	✓	✓	✓	✓	15	✓
Pu-239	✓	✓	✓	—	✓	✓	✓	✓	✓	26	✓
Pu-240	—	✓	✓	—	✓	✓	✓	✓	✓	21	✓
Pu-241	—	✓	—	—	✓	✓	✓	✓	✓	17	✓
Pu-242	—	—	—	—	✓	✓	✓	✓	✓	11	✓
Pu-244	—	—	—	—	✓	—	—	—	—	3	—
Am-241	✓	✓	—	—	✓	✓	✓	✓	✓	22	✓
Am-242	—	—	—	—	—	—	—	—	✓	2	—

Table D-6 (continued)

Nuclide	Source (weighting factor)									Score	Include
	NUREG/ CR-0134	IAEA 1996	WINCO 1191	NUREG/ CR-0130	NUREG/ CR-3585	NUREG/ CR-4370	SAND 92 -0700	ORIGEN	SAND 91-2795		
	(5)	(6)	(4)	(4)	(3)	(2)	(2)	(2)	(2)		
Am-242m	—	—	—	—	—	—	—	✓	—	2	—
Am-243	—	—	—	—	✓	✓	—	✓	✓	9	—
Cm-242	—	—	—	—	—	✓	—	—	—	2	—
Cm-243	—	—	—	—	✓	✓	—	✓	✓	9	—
Cm-244	—	✓	✓	—	✓	✓	✓	✓	✓	21	✓
Cm-245	—	—	—	—	—	—	—	✓	✓	4	—
Cm-246	—	—	—	—	—	—	—	—	✓	2	—
Cm-248	—	—	—	—	✓	—	—	—	—	3	—
Cf-252	—	—	—	—	✓	—	✓	—	—	5	—

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